(See *Contributions* No. 7.) Special studies with the spectroheliograph are also in progress. An account of the work on spot spectra and on the motion of the calcium vapor may be found in *Contributions* Nos. 5 and 6. Special apparatus for the spectrographic study of the solar rotation has been nearly completed in our instrument-shop. The study of the solar radiation has so far been confined to the investigations of the Smithsonian expedition (June-November, 1905), but arrangements have been made to continue this work next year. Laboratory researches will be undertaken shortly with instruments which are now being installed.

GEORGE E. HALE.

SOLAR OBSERVATORY.

FIRST CATALOGUE OF SPECTROSCOPIC BINARIES.[1]

The application of the Doppler-Fizeau principle to the study of the stars, by photographic means, has led to the discovery of an entirely new class of stellar systems, known as spectroscopic binaries. This term is in general applied to those stars which are apparently single when viewed through our most powerful telescopes, but which the spectrograph has shown to be accompanied by invisible companions. However, the condition that the companions shall be invisible is too limited, and it is more satisfactory to class with the spectroscopic binaries all stars whose radial velocities have been observed to vary. The discovery of the first spectroscopic binary, *ζ Ursæ Majoris,* was made by Professor PICKERING in 1889. The objective-prism spectrograms of this star showed that it consisted of two components, approximately equal in brightness, in rapid revolution around their center of mass. The second discovery, made by Professor VOGEL from plates secured with a slit spectrograph, related to *Algol* and the massive and relatively very dark companion which partially occults the bright primary, for terrestrial observers, once each revolution. In successive years additions to the list were made by PICKERING, VOGEL, BELOPOLSKY, Miss MAURY, Mrs. FLEMING, and BAILEY, until, in the summer of 1898, thirteen spectroscopic binaries were known. Since that date the number has increased with great rapidity. The systems observed up

[1] Extract from the *Lick Observatory Bulletin* No. 79.

to January 1, 1905, numbered one hundred and forty. A tabulation of these by observatories may be of interest.

Lick Observatory (Mills spectrograph)	58
Lick Observatory (D. O. Mills expedition to the Southern Hemisphere)	14
Yerkes Observatory (Bruce spectrograph)	41
Harvard College Observatory	8
Lowell Observatory	7
Pulkova Observatory	6
Potsdam Observatory	4
Meudon Observatory	2
Cambridge Observatory	1
Visual binaries observed radially, but without variation	6
	147
Deduct for binaries independently discovered at two observatories	7
Total	140

The literature concerning the discovery, observation, and study of these systems is quite widely scattered, and the requirements of the work with the Mills spectrograph have led us to collect and tabulate the data. The time appears to have arrived when their publication, in a form which we venture to entitle a "First Catalogue of Spectroscopic Binaries," will prove useful to many investigators in this and other departments of astronomy.

[The catalogue, covering eight quarto pages of tabular matter, is here omitted.]

Strictly speaking, the six stars, α_1 – α_2 *Geminorum,* γ *Leonis,* γ *Virginis,* α *Centauri,* 61 *Cygni,* and δ *Equulei,* have not yet been observed as spectroscopic binaries. The *differences* of the radial speeds of their components have been measured, but these differences have not been observed to vary. However, their inclusion is a convenience and, we think, unobjectionable. While every visual binary carries the possibility of measurement as a spectroscopic binary, the number of such stars available for observation in the near future is limited, and all such may well be placed upon the spectrographic observing-list.

The number of spectroscopic binary systems not resolvable by our powerful telescopes is relatively very large. Of the

stars studied with the Mills spectrograph, at least one in seven seems to be an invisible binary of short period. For the *"Orion"* type of stars, observed especially with the Bruce spectrograph, the remarkable proportion of one in three was found.

Only those systems have been detected whose periods are relatively short, and for which the variations of radial speed are considerable. The smallest observed variation is that of *Polaris,*—six kilometers per second. Had the variation for *Polaris* been only one kilometer, it would no doubt have escaped detection. Such a variation could be measured by present instruments and methods; but this range would not have excited the observer's suspicion, and the discovery would have remained for the future. It is probable that there are more systems with variations of speed under six kilometers than there are with larger ones; and all such are awaiting discovery. The velocity of our Sun through space varies slightly, because it is attended by companions,—very minute ones compared with the invisible bodies discovered in spectroscopic binary systems. It is revolving around the center of mass of itself and its planets and their moons. Its orbit around this center is small, and the orbital speed very slight. The total range of speed is but three one-hundredths of a kilometer per second. An observer favorably situated in another system, provided with instruments enabling him to measure speeds with absolute accuracy, could detect this variation, and in time say that our Sun is attended by planets. At present, terrestrial observers have not the power to measure such minute variations. As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. In fact, the star which seems not to be attended by dark companions may be the rare exception. There is the further possibility that the stars attended by massive companions, rather than by small planets, are in a decided majority; suggesting, at least, that our solar system may prove to be an extreme type of system, rather than a common or average type.

The number of spectroscopic binaries discoverable by present means is certainly a large proportion of the stars brighter than the eighth photographic magnitude. This is about the present limit for successful observation. It must be remem-

bered that in a spectrum the light is spread over a large area. The recording of the spectrum of a ninth-magnitude star, using moderate dispersion, is perhaps comparable with photographing a twentieth-magnitude star by means of our powerful reflecting telescopes. Further, the successful measurement of moderate dispersion spectrograms requires that the image be of good intensity and that the observational conditions be favorable.

In any given list of stars the number of binaries discoverable by spectrographic means seems to exceed greatly the number observable visually. Messrs. HUSSEY and AITKEN have found that of stars brighter than the ninth magnitude, one in eighteen is double in the 36-inch refractor, with components less than 5″ apart. This limit of 5″ represents in general a continually increasing linear separation of the components as we pass to fainter and fainter stars. The ability of the spectrograph to resolve close pairs, on the other hand, is independent of their distances from us, provided they supply sufficient light for accurate observation and their spectra contain measurable lines.

The companions of binaries discovered by means of the spectrograph have not been observed visually in our powerful telescopes, although they have been carefully searched for. They may be so close to the principal star that, viewed from our distance, the two images cannot be resolved. The separation of the components is probably less than one hundredth of a second of arc for most of the binaries thus far announced. Again, for very few of the systems are the spectra of both components recorded. This does not establish that the companion is a dark body, but only that it is at least one or two photographic magnitudes fainter than the primary. The fourth-magnitude companion of a second-magnitude star would scarcely be able to impress its lines upon the primary's spectrum. The invisible components in many spectrographic binaries might be conspicuous stars if they stood alone.

It is evident that future catalogues of spectroscopic binaries will contain thousands of entries. It will be neither possible nor desirable for them to include the observational data. Mainly for this reason we have decided in the present catalogue to let references to the original publication suffice in nearly all cases.

The blank spaces in the columns of orbital elements emphasize the strong need for work in that direction. There can be little doubt that a comparative study of spectroscopic orbits and of spectroscopic and visual orbits would be most fruitful of results.

W. W. CAMPBELL,
HEBER D. CURTIS.

THE SPECTROGRAPHIC BINARY, Y *OPHIUCHI.*

During the summer and fall of 1905 a good series of spectrograms of the variable star Y *Ophiuchi* were obtained with the one-prism spectrograph. The plates thus far measured and reduced give a velocity-curve of double amplitude of about 20^{km} and a period coinciding with the period of light variation, which is 17.12 days. The minimum velocity seems to occur about two days after the epoch of light-maximum.

January 25, 1906. SEB. ALBRECHT.

NOTE ON THE RECENT OBSERVATIONS OF THE RADIAL VELOCITY OF *a DRACONIS.*

a	$14^h\ 1^m.7$	Type A	Vis. magn. 3.6
δ	$+64^\circ\ 51'$		Photo. magn. 4.0

a Draconis was announced as a spectroscopic binary by Director CAMPBELL and Dr. H. D. CURTIS in 1903 (*L. O. Bulletin* No. 46) from an observation of its radial velocity in 1902, and two in 1903. The first plate of June 16, 1902, gave a velocity of $\pm 0^{km}$, while the plates of April 29th and May 4th gave velocities of -43^{km} and -42^{km}, respectively. Three plates have been obtained since the above, the measures of which, made by the author, are as follows:—

Plate.	Date.	Velocity.
3272B	1904 June 19	-42^{km}
3831B	1905 June 13	-42
4152E	1906 January 4	-40

Director CAMPBELL has asked me to call attention to the fact that our recent measures agree among themselves, and with those of April 29 and May 4, 1903, so that the binary character of *a Draconis* rests upon the plate of June 16, 1902. The velocity from this plate is based upon the magnesium line 4481, which is slightly out of focus. Repeated measures by